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Inventors: Katsuhito Kitahara, et al. Group No. 2672

Serial No.: 10/026,157 Examiner: M. Razavi

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Title: System And Method For Processing Image Data, Computer Program For Performing The Method And Data Storage Medium Carrying The Program

CERTIFICATE OF MAILING

I hereby certify that this transmittal and the documents attached hereto are, on this date, being deposited with the United States Postal Service with sufficient postage as First Class mail in an envelope addressed to the Assistant Commissioner for Patents, Washington, D.C. 20231.

Date: October 7, 2002

Virginia Silva

Submission of English Translation of Non-English Language Provisional Application in Support of Claiming Benefit of Earlier Filing Date Under 37 C.F.R. §1.78(a)(5)

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

Enclosed is an English translation and accompanying statement of accuracy of translation of the non-English language provisional application filed on September 7, 2001 to which this application claims priority.

Respectfully submitted,

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In Re Application of: Katsuhito Kitahara, et al.

Serial No.: 10/026,157 Group No.: Not Yet Assigned

Filed: December 18, 2001 Examiner: Not Yet Assigned

Title: SYSTEM AND METHOD FOR PROCESSING IMAGE DATA, COMPUTER PROGRAM FOR PERFORMING THE METHOD AND DATA STORAGE MEDIUM CARRYING THE PROGRAM

Assistant Commissioner for Patents
Washington, D.C. 20231

STATEMENT OF ACCURACY OF TRANSLATION
(37 C.F.R.§§ 1.52(d), 1.55(a), 1.69)

I, the below named translator, hereby state:

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The document for which the attached English translation is being submitted is

U. S. Provisional Patent Application No. 60/317,782 (Atty Docket No.: P6405PR)

[x] This foreign language document was filed in the PTO on September 7, 2001.

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Full name of the translator: Clifford E. Bender

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[Document title] Specification
[Title of the invention]

Image processing apparatus for printing, method for processing image, and recording medium storing the method

[DETAILED DESCRIPTION OF THE INVENTION]
[0001]

[Technical field of the invention]

The present invention relates to an image processing apparatus for printing and an processing image method for a printer for assigning colors in an original image to a limited number of print colors when printing a full-color original image or original image containing other color image data and/or text data. This invention relates more specifically to an image processing apparatus and method for printing that is highly compatible with a color printer capable of printing only limited specific colors (referred to herein as a "color-limited printer"). It should be noted that the original image to which color reduction and color assignment processes are applied is referred to herein as the "source data."
[0002]

[Prior art]

By using 256 levels each for red, green, and blue, modern graphics processes can express more than 16 million colors in a full-color image. Full-color printers capable of printing these images are also now commonly available.
[0003]

While printers used in business have primarily been monochrome printers because of speed and economy considerations, color printers are now also now beginning to be used in business settings. While full-color printers offer the advantage of providing a wide range of color expression, the drawbacks are that color printing takes longer and operating costs are higher. With printers used for specific business applications where high speed printing is particularly important, such as where there is a 1:1 relationship between a customer and the printing operation and printer output is handed directly to the customer on the spot, it is necessary to balance the desire for the expressiveness that is possible with color printing with the need for fast printing, and two-color printers, that is, printers limited to printing two colors, are therefore beginning to be used.

Examples of this type of business printer include POS printers in the distribution industry, ATM printers used in banks, printers for printing tickets for parking lots and customer service queuing numbers, and printers used in kiosk terminals in convenience stores. Because the primary object of such printers is to print text and text data is typically printed in black, two-color printers capable of printing black and one other color (normally red, green, or blue) as the colors printable by such color-limited printers are generally used, but three-color printer capable of printing two colors in addition to black are also possible.
[0004]

In order to print an image such as a full-color image containing many colors on this type of color-limited printer, the source data must be reduced to the colors that can be printed by the printer. In addition to enabling printing full-color images on a color-limited printer, there are also cases in which it is desirable to print an image using a limited number of colors, such as when a particular color of ink becomes low.

[0005]

[Problem to be solved by the invention]

Methods for reducing the colors in a full-color or other image containing many colors include simple color reduction, dithering, and error diffusion. Dithering and error diffusion, however, sometimes introduce a fine noise pattern as a result of the color reduction process. When such an image is then printed with only a few colors, the spots are emphasized. Furthermore, because the shape of a logo is particularly important, the contours and shape of the logo are preferably clearly represented even when printed with a limited number of colors. Some modern logos combine a complex blend of colors and color brightness (appearing as a difference in luminance during image processing).

Simple color reduction techniques simply digitize RGB color depth referenced to a defined median value, thus emphasizing the color difference and not clearly reflecting the difference in brightness. The result is that when such a logo is reduced with simple color reduction, the luminance difference is not accurately presented and the printed logo may differ greatly from the original logo.

[0006]

The present invention is directed to a solution for the above problems, and an object of this invention is to provide an image processing apparatus for printing and method for a printer for generating print image data for printing a source image accurately and clearly using limited colors when the source image presents specific shapes using luminance difference information.

[0007]

A further object of this invention is to provide an image processing apparatus for printing and method capable of applying various image processes as a result of being able to create a print image emphasizing luminance when printing an image using fewer colors than in the source image. When printing a logo or other image suitable to a particular printing objective, such as announcement information, product advertisement, or coupon, using limited colors, it is desirable to be able to use the widest range of image processes from the perspective of creating an optimal print image.

[0008]

[Means for solving the problem]

The present invention converts source image data from color data to luminance data by converting color data for each pixel unit in the source data, where the source data is image data containing multiple colors, to corresponding luminance data, then assigning the luminance data for each pixel based on the luminance level to a color that can be printed by the printer, and thereby enables

creating a print image referenced to the luminance levels of the source data image. It is thereby possible to generate print image data for accurately and clearly printing a source image with limited colors. It is therefore possible to provide an image processing apparatus for printing and method that can apply various image processes based on luminance information in addition to dithering and other color reduction methods in order to print a source image using few colors.

[0009]

An image processing apparatus for printing according to a first aspect of the present invention has a source data capturing control unit for obtaining source data containing image data and/or text data containing plural colors; a data conversion processing unit for converting all source data from color data to luminance data by converting color data for each pixel unit in the captured source data to luminance data; and a color assignment processing unit for assigning a print color according to the luminance level of the luminance data for each pixel.

[0010]

Print colors can thus be assigned based on image luminance, thereby preventing the fine spots that occur with color reduction and creating an image that is clearly-defined when printed with few colors.

[0011]

An image processing apparatus for printing according to a second aspect of this invention is characterized by the data conversion processing unit converting the source data overall to gray scale luminance data by calculating an overall luminance value for each pixel unit in the captured source data from color depth data for each red, blue, and green color in the RGB color data for each pixel unit, and using the calculated luminance as the luminance data for the corresponding pixel. Because each pixel in a full-color image is normally expressed by RGB color depth, the three RGB color data values for each pixel are combined to calculate a single luminance value.

[0012]

An image processing apparatus for printing according to a third aspect of this invention is characterized by the data conversion processing unit luminance correcting the color depth data of the RGB data for each pixel with a respective specific value, and setting an average of luminance-corrected color depth data for each pixel as the luminance of a corresponding pixel. This compensates for any offset between color depth and luminance, and makes it possible to calculate an accurate luminance value for each pixel unit.

[0013]

An image processing apparatus for printing according to a fourth aspect of this invention is characterized by the data conversion processing unit calculating luminance by weighting color depth data for the RGB data of each pixel unit using an R:G:B ratio equal or approximately equal to 3:1:6. This is to apply luminance correction according to the characteristics of each RGB color.

[0014]

An image processing apparatus for printing according to a fifth aspect of this invention is characterized by the data conversion processing unit comprising a level conversion processing unit for reducing calculated luminance data to a smaller number of luminance levels. This method further reduces 256 luminance levels to 8 levels, for example. This can simplify the color assignment process, and makes the color assignment process easier by viewing an image presented by luminance data reduced to a few luminance levels.

[0015]

An image processing apparatus for printing according to a sixth aspect of this invention is characterized by the level conversion processing unit determining a pixel count for each luminance level in all luminance data converted from the source data and a distribution of said pixel counts for each luminance level, detecting a minimum in the pixel count distribution from the pixel count distribution curve and setting a threshold value based on the luminance level of the detected minimum, and converting the luminance data to a smaller number of luminance levels using the threshold value. A print image more accurately reflecting luminance as a component of the image can thus be created by setting threshold values for reducing the number of luminance levels based on luminance levels in the image having a low pixel count.

[0016]

An image processing apparatus for printing according to a seventh aspect of this invention is characterized by the level conversion processing unit detecting as a minimum a transition point from a decrease to an increase where the pixel count at each point on the distribution curve begins to increase for a specified number of data points after decreasing continuously for a specified number of data points. This technique prevents using minimums forming small valleys as threshold values, and thus more accurately reflects luminance differences in the print image.

[0017]

An image processing apparatus for printing according to an eighth aspect of this invention is characterized by the level conversion processing unit not using as a basis for setting a threshold value any minimum of the distribution curve where the pixel count is greater than or equal to a specific number. This technique eliminates minimums forming shallow valleys from being used as threshold values, and thus more accurately reflects luminance differences in the print image.

[0018]

An image processing apparatus for printing according to a ninth aspect of this invention is characterized by the level conversion processing unit further smoothing the distribution curve of the calculated pixel counts, and detecting the minimums from the smoothed distribution curve. This smoothing process removes small fluctuations in the pixel count distribution, reflects large changes in the luminance in the distribution curve, and is thus able to detect more appropriate threshold values.

[0019]

An image processing apparatus for printing according to a tenth aspect of this invention is characterized by the level conversion processing unit converting the color data for each pixel unit in the source data to eight level luminance data. Converting the image to approximately 8 gray levels makes it possible to accurately express large changes in image luminance, and makes it easier to assign colors using a further 2-value or 3-value conversion. It is also easier to set the threshold values visually.

[0020]

An image processing apparatus for printing according to an eleventh aspect of this invention is characterized by the color assignment processing unit converting the luminance levels to N levels according to the number N of print colors, and assigning luminance levels to print colors according to the N luminance levels. The number of print colors N includes the non-printing color of the paper, typically white, includes color gradations that can be expressed with dithering to represent different tones using multiple dots, and includes tones that can be printed with overstriking and other such printing techniques. It will be noted that by increasing the number of luminance levels resulting from the luminance level conversion step as the number printable colors increases, greater detail can be achieved in the print image.

[0021]

An image processing apparatus for printing according to a twelfth aspect of this invention is characterized by the assignment processing unit comprising a color assignment selection unit for specifying the print colors. This enables the print color assignments to be externally input. There are cases when it is desirable to change an assignment as a result of a final color assignment evaluation based on visual confirmation, assignment settings can be externally input in such cases, and the invention is thus useful in such cases.

[0022]

An image processing apparatus for printing according to a thirteenth aspect of this invention is characterized by the color assignment processing unit being able to assign as the print colors a plurality of printable colors that can be expressed by dithering colors of usable ink. This enables a rich variety of color expression. When numerous colors are printed by increasing the number of printable colors using such color gradations, the number of luminance levels must be increased according to the number N of print colors.

[0023]

An image processing apparatus for printing according to a fourteenth aspect of this invention is characterized by the color assignment processing unit assigning print colors printable by a color-limited printer. This invention is not limited to use with printers capable of printing only limited colors, but is particularly effective for creating print images for printing by a color-limited printer.

[0024]

An image processing apparatus for printing according to a fifteenth aspect of this invention is characterized by the color-

limited printer being a POS printer connected to a POS terminal. The present invention is particularly advantageous when used as an print image processing apparatus for generating logo data to be printed from a POS printer.

[0025]

A first aspect of a print image processing method according to the present invention is characterized by comprising (a) a step for obtaining and storing image data and/or text data containing plural colors; (b) a data conversion processing step for converting all source data from color data to luminance data by converting color data for each pixel unit in the captured source data to luminance data; and (c) a color assignment processing step for assigning a print color according to the luminance level of the luminance data for each pixel.

[0026]

A print image processing method according to a second aspect of this invention is characterized by the (b) data conversion processing step converting the source data overall to gray scale luminance data by calculating an overall luminance value for each pixel unit in the captured source data from color depth data for each red, blue, and green color in the RGB color data for each pixel unit, and using the calculated luminance as the luminance data for the corresponding pixel.

[0027]

A print image processing method according to a third aspect of this invention is characterized by the (b) data conversion processing step luminance correcting the color depth data of the RGB data for each pixel with a respective specific value, and setting an average of luminance-corrected color depth data for each pixel as the luminance of a corresponding pixel.

[0028]

A print image processing method according to a fourth aspect of this invention is characterized by the (b) data conversion processing step calculating luminance by weighting color depth data for the RGB data of each pixel unit using an R:G:B ratio equal or approximately equal to 3:1:6.

[0029]

A print image processing method according to a fifth aspect of this invention is characterized by the (b) data conversion processing step comprising a level conversion processing step for reducing calculated luminance data to a smaller number of luminance levels.

[0030]

A print image processing method according to a sixth aspect of this invention is characterized by the level conversion processing step determining a pixel count for each luminance level in all luminance data converted from the source data and a distribution of said pixel counts for each luminance level, detecting a minimum in the pixel count distribution from the pixel count distribution curve and setting a threshold value based on the luminance level of the detected minimum, and converting the luminance data to a smaller number of luminance levels using the threshold value.

[0031]

A print image processing method according to a seventh aspect of this invention is characterized by the level conversion processing step detecting as a minimum a transition point from a decrease to an increase where the pixel count at each point on the distribution curve begins to increase for a specified number of data points after decreasing continuously for a specified number of data points.

[0032]

A print image processing method according to an eighth aspect of this invention is characterized by the level conversion processing step not using as a basis for setting a threshold value any minimum of the distribution curve where the pixel count is greater than or equal to a specific number.

[0033]

A print image processing method according to a ninth aspect of this invention is characterized by the level conversion processing step further smoothing the distribution curve of the calculated pixel counts, and detecting the minimums from the smoothed distribution curve.

[0034]

A print image processing method according to a tenth aspect of this invention is characterized by the level conversion processing step converting the color data for each pixel unit in the source data to eight level luminance data.

[0035]

A print image processing method according to an eleventh aspect of this invention is characterized by the (c) color assignment processing step converting the luminance levels to N levels according to the number N of print colors, and assigning luminance levels to print colors according to the N luminance levels.

[0036]

A print image processing method according to a twelfth aspect of this invention is characterized by the (c) color assignment processing step comprising a color assignment selection unit for specifying the print colors.

[0037]

A print image processing method according to a thirteenth aspect of this invention is characterized by the (c) color assignment processing step being able to assign as the print colors a plurality of printable colors that can be expressed by dithering colors of usable ink.

[0038]

A print image processing method according to a fourteenth aspect of this invention is characterized by the (c) color assignment processing step assigning print colors printable by a color-limited printer.

[0039]

A print image processing method according to a fifteenth aspect of this invention is characterized by the color-limited printer being a POS printer connected to a POS terminal.

[0040]

A further aspect of the invention achieves the functions of the present invention with a central processing unit (CPU), ROM, RAM, display device, input/output device, interface, and a control program and data set stored in ROM, RAM. The control program and data set, and a data storage medium recording the control program and data set, are also included as embodiments of the present invention.

[0041]

[Preferred embodiments of the invention]

A preferred embodiment of the present invention is described below. It will be noted that the following embodiments are shown by way of example only and shall not limit the scope of the invention. It will be obvious to one with ordinary skill in the related art that various alternative embodiments can be achieved by replacing some or all of the elements described below with an equivalent, and that all such variations are included in the scope of this invention.

[0042]

(Main applications and need for the invention: growing use of printing color images with limited colors)

The present invention is particularly useful for image processing data to be printed on a color-limited printer used in specialized business applications. This type of color-limited printer for such specialized business applications has recently begun to be used for POS system printers (referred to below as a POS printer). POS systems store sales data about the products available for purchase by a customer on a POS server, and print the purchased items and cost information from a POS printer to paper then issued as a receipt for each customer. The receipt is then handed directly to the customer. The store's logo, product advertisements, announcements, and other information may also be printed in addition to the sales data to the receipt. The POS system can also use the POS printer to print coupons, free offers, and other sales promotions. Logos, advertisements, notices, coupons, and other such information printed on the receipt also have an effect on the company's image and effectiveness of the offer, and good logo design enabling easy brand recognition is therefore desirable. Color printing in limited colors is able to balance rich expressiveness with high speed printing performance.

[0043]

In order to address both the need for immediate printing (high speed printing) in direct customer transaction situations, and the need for color printing, it is necessary to balance high speed communication with economy. One method of addressing this is the technique of storing a particular print image as logo data in the printer and printing the stored image as a logo by means of a particular print command. The most typical current use of generating reduced-color image data for a color-limited printer used in such special applications is therefore creating the logo data stored in such color-limited printers.

[0044]

It will also be noted that a logo generally refers to data such as a store logo printed by a POS printer. As used herein,

however, a logo refers to all data stored in a printer for printing, and specifically includes image data for product advertisements, image data for announcements and notices, image data for coupons, and image data for discount tickets.

[0045]

Furthermore, while a POS printer is as described above a typical example of a special application in which a color-limited printer can be used, color-limited printers are not limited to POS printing applications and can also be for other applications. Logos, advertisements, announcements and the like can also be printed on printers used for bank ATM printers, customer service (queuing) number printers, and parking lot ticket printers, and because immediate printing is also required color-limited printers are expected to occupy an increasingly important position in these applications as in the POS printer market. This invention is effective for creating reduced-color images for printing on color-limited printers such as described above. Our invention shall not be limited to use with such color-limited printers, however, and can be used with full-color printers to, for example, intentionally reduce a full-color image to a specific number of print colors in order to emphasize a particular color or image element.

[0046]

The most typical field in which we expect the invention to be used, however, is for business printers such as POS printers and ATM printers. When describing a specific printing situation, the following description of the invention therefore imagines printing from a color-limited printer such as described above, and even more particularly from a POS printer.

[0047]

(Overview of printing images with a printer)

A printer prints by receiving print data and print commands. POS printers can likewise print by receiving the print data for each print job. When printing is thus accomplished by receiving the print data each time the data is printed, printing becomes slower because image data files are large and take much time to transmit. POS printers therefore register frequently printed image data as logo data inside the printer, and read and print the logo data from memory when a particular logo data print command is received. If the image data printed in this manner is a color image, RGB color data is converted to CMYK and then printed. When the logo data is color, it is stored as color data for each pixel in non-volatile memory inside the printer. The stored color data can be stored as RGB color data but is generally stored as CMYK color data so that it can be printed directly without an intervening conversion process. As thus noted, conversion from RGB color to CMYK is necessary for color printing, but because such conversion techniques are commonly known the present invention is described below with reference only to image processing RGB color data. The print image generated by the present invention is ultimately converted to CMYK color data and printed or stored (registered) as logo data.

[0048]

A typical procedure for printing a logo stored as image data inside a POS printer is described next below without referring to the accompanying figures. When a print logo command is received, the printer reads the logo data specified by the received print command and converts the stored logo data to the color image data that will actually be printed from the print buffer. Each dot in the image for each color is stored digitized for each print color. The digitized dot data for each dot unit stored to the print buffer is sent to the print mechanism according to each print color as controlled by the printing control unit. The print mechanism sequentially prints the dot data received from the print buffer by means of a print head for each print color while conveying the receipt paper so that it passes in front of the print head. A logo is thus printed to a specific location on the receipt.

[0049]

This invention creates the print image sent to the printer for printing in this manner, and further description of the image printing operation itself is therefore omitted below.

[0050]

(Preferred embodiment of an image processing apparatus for printing)

Fig. 1 is a function block diagram of a print image processing apparatus 10 according to a preferred embodiment of the present invention. As shown in Fig. 1, the print image processing apparatus 10 has a source data capturing control means 11, parameter input controller 12, color assignment processor 13, display controller 14, data conversion processor 15, data storage unit 20, and print data output controller 24. The data conversion processor 15 has a source data reading unit 16, luminance calculator and storage unit 17, and gradation processing unit 18. The data storage unit 20 includes source data memory 21, luminance data memory 22, and print data memory 23.

[0051]

The source data capturing control means 11 is a file reading controller, scanner, or similar device for capturing a full-color image or other image data from which the print image will be generated by scanning an image or reading an image stored to an external disk, CD-ROM, memory card, or other storage device or medium. The source data is then stored to the source data memory 21 in data storage unit 20 as RGB color data for each pixel. The source data stored to source data memory 21 is read pixel by pixel by the source data reading unit 16 of data conversion processor 15, and is sent to the luminance calculator and storage unit 17. The luminance calculator and storage unit 17 calculates the luminance value for the each pixel as further described below, and stores the result. The luminance data calculated for each pixel is further converted by the gradation processing unit 18 to luminance data with even fewer levels. The gradation processing unit 18 is further described below. The luminance data converted to gray level data by the gradation processing unit 18 is stored to the luminance data memory 22 in data storage unit 20.

[0052]

The luminance data converted from the color data and then further converted and stored to the data storage unit 20 is read by the color assignment processor 13, which then assigns a specific color according to the luminance levels. Operation of the color assignment processor 13 is also further described below. The image data to which colors are assigned by the color assignment processor 13 is then stored as print data to the print data memory 23. The print data stored to the print data memory 23 can be output by the print data output controller 24 as a logo data file or output as print data to the printer, for example, or output to another convertor or processor for conversion from RGB color data to CMYK color data, for example.

[0053]

The parameter input controller 12 enables inputting data for setting the parameters and conditions of certain image processing operations (referred to below as the parameter data), including the threshold values used by the gradation processing unit 18 for downsampling luminance data to a smaller number of gray levels, and the color assignments of the color assignment processor 13 for assigning colors, and controls passing the input parameter data to the gradation processing unit 18 or color assignment processor 13. The display controller 14 controls displaying on the display unit the source data obtained by the source data capturing control means 11 and stored to the source data memory 21, and the print data stored to the print data memory 23 after image processing. During image processing the image processing parameters can be changed to create the best print data while viewing both the source data and print data resulting from the current parameter settings on the display unit.

[0054]

(Luminance data calculation)

Calculating the luminance data is described next. Luminance data is calculated by the luminance calculator and storage unit 17 from the RGB color data. Color image data is commonly expressed using three colors, specifically red, green, and blue, per pixel and setting each color to a particular color depth ranging from 0 to 255 (256 levels). Each pixel can therefore be theoretically defined as one of more than 16 million colors (256 x 256 x 256 = 16,777,216) in a full-color image. Luminance is not directly proportional to color depth, and luminance varies according to the color depth of each color (R:G:B). The luminance Yc of each pixel is calculated using the following equation to convert RGB color data to luminance data.

[0055]

$$Y = 0.299R + 0.587G + 0.114B \qquad (1)$$

If full-color image data is read by the source data capturing control means 11 and processed as the source data, that is, if the RGB color depth is 0 to 255, conversion to 256 luminance levels (0 to 255) is possible using the equation

$$Y = \mathrm{int}((0.299R/256 + 0.587G/256 + 0.114B/256) \times 256) \qquad (2)$$

and conversion to 8 levels (0 to 7) is possible using the equation

$$Y = \mathrm{int}((0.299R/256 + 0.587G/256 + 0.114B/256) \times 8) \qquad (3).$$

[0056]

Fig. 2 shows the relationship between color depth and luminance for the typical colors white (W), yellow (Y), cyan (C), green (G), magenta (M), red (R), blue (B), and black (K). RGB color depth and luminance (Y256 = 256 levels, Y8 = 8 levels) are shown for each of the colors W, Y, C, G, M, R, B, K.

[0057]

(Downsampling luminance to fewer luminance levels)

A conversion process whereby the gradation processing unit 18 reduces the number of luminance levels is described next with reference to Fig. 3.

Fig. 3 is a function block diagram of a gradation processing unit 18 according to a preferred embodiment of the invention. It is assumed here that the luminance calculator and storage unit 17 has converted RGB color data to 256-level luminance data. Because the source data image is expressed using 256 levels of luminance data at this stage, it cannot be printed on a printer with only a few colors. The color combinations are also too complex to assign colors at this stage. The 256-level luminance data representing an image in 256 luminance levels is therefore converted by the gradation processing unit 18 to luminance data with fewer luminance levels (8 levels, for example).

[0058]

It will be noted that this step of further reducing the number of luminance levels is not required if, for example, the luminance calculator and storage unit 17 has already reduced the source data image to 8 luminance levels by applying the above equation (3). However, if the luminance calculator and storage unit 17 initially reduces the image to 8 luminance levels, the process for optimal image processing according to change in luminance could become complex. The downsampling process to fewer gradations is performed to set the threshold values for determining if optimal image printing is possible when the image is printed with few colors. The optimum threshold values are therefore found by first converting the luminance value of each pixel to finely graded luminance data and then determining which luminance level used as the threshold value for assigning colors to the converted luminance data will enable the best image when printed with few colors.

The gradation processing unit 18 shown in Fig. 3 detects the luminance levels for which the pixel count is less than the pixel count of the luminance levels therebefore and thereafter, and uses these luminance levels as the threshold values for color assignment. To achieve this the gradation processing unit 18 detects a pixel count distribution curve from each pixel count luminance level for the entire image, and determines the luminance level to be used as the threshold value from the minimum of the distribution curve.

[0059]

This process could be skipped and the threshold values determined by evenly dividing the luminance levels converted by the luminance calculator and storage unit 17, and the image then converted to a low resolution gray level image using these threshold values, but the threshold values obtained by such even division will not accurately reflect the change in luminance that

is characteristic of the source data, and the pattern of the resulting print image may be completely different from the source image. It is therefore desirable to determine the threshold values characteristic of the image by first analyzing the luminance distribution of the source image. The gradation processing unit 18 in Fig. 3 is further described below.

[0060]

(Detecting the pixel count distribution in each luminance level)

As shown in Fig. 3, the gradation processing unit 18 has a pixel counter 31, pixel count distribution memory 32, distribution curve smoothing processor 33, minimum detection controller 34, threshold value selector 35, and luminance data conversion processor 36. The pixel counter 31 reads the luminance data for the entire luminance image converted to luminance data and stored by the luminance calculator and storage unit 17, accumulates the number of pixels in each luminance level, and thus determines the pixel count for each luminance level. The distribution of the pixel count determined for each luminance level is then stored to the pixel count distribution memory 32.

[0061]

(Distribution curve smoothing process)

Fig. 4 is a graph showing the pixel count distribution stored in pixel count distribution memory 32 as a distribution curve. Note that Fig. 4 shows a section of the 0 to 255 luminance levels enlarged in order to simplify this description of the smoothing process. The distribution of luminance data stored to the pixel count distribution memory 32 is shown as luminance distribution curve 37. The luminance distribution curve 37 is a graph of the points indicating the pixel count for the luminance values digitized to one of 256 levels. High resolution conversion of the luminance data produces a luminance distribution curve 37 having low minimums 51 distributed throughout the distribution curve. The luminance levels at these minimums are unsuitable for use as the threshold values for downsampling the data to fewer gray levels, and are therefore preferably removed.

[0062]

These minimums are removed by the distribution curve smoothing processor 33 smoothing the luminance distribution curve 37. The distribution curve smoothing processor 33 smoothes the luminance distribution curve 37 by, for example, calculating the average of m (where m = 3, for example) data points before and after each point in the luminance distribution curve 37, and then using the resulting average as the pixel count for that luminance level. As shown by the smoothed distribution curve 38 in Fig. 4, the low minimum 51 in the luminance distribution curve before smoothing does not appear in the smoothed distribution curve 38 after smoothing, and it is therefore easier to find the best threshold values.

[0063]

(Detecting the minimums)

The minimum detection controller 34 detects the minimums from the luminance data distribution after smoothing. Minimums can be

detected by, for example, finding a point at which the pixel count decreases through k (5, for example) consecutive data points and then increases through the next j (5, for example) consecutive data points. It should be noted that applying this condition that the pixel count decreases and increases consecutively also makes it possible to eliminate values, such as minimum 52, in the smoothed distribution curve that are unsuitable for determining the threshold values. It should be noted that various other methods that will be apparent to one with ordinary skill in the art can also be used for minimum detection.

[0064]

(Determining the threshold values)

Once the minimums are detected, the threshold values are then set using the luminance value of the detected minimums. The number of gradation levels resulting from the low resolution conversion process can be predetermined or can be input from the parameter input controller 12. If the number of minimums is less than the desired number of gradations levels, the data is converted to the specified number of levels using a predetermined algorithm. For example, luminance levels could be divided in two starting from luminance levels with the greatest distance therebetween and the resulting values used as the threshold values. Operation could also be configured so that rather than applying image analysis using the pixel count distribution as described above, parameters externally input using the parameter input controller 12 are used to determine the threshold values for low resolution conversion. This is because there are cases where the best threshold values can be set based on visual perception alone.

[0065]

Fig. 6 is a graph showing an example of downsampling the luminance data to eight levels based on seven threshold values 1 to 7 determined by the gradation processing unit 18. The threshold values 1 to 7 are set to the valleys (minimums) of the pixel count distribution curve in Fig. 6. Note that when there is a sharp valley at each end of the distribution curve as shown in Fig. 6 it is also useful to ignore minimums detected in such valleys at each end of the distribution curve. In this case it is necessary to set a specific width from each end where values are ignored.

[0066]

(Conversion process for low resolution downsampling)

The luminance data conversion processor 36 reads the luminance data for each pixel from the luminance calculator and storage unit 17, and based on the defined threshold values converts each pixel to luminance data at one of the eight luminance levels, for example. The converted luminance data is then stored to the luminance data memory 22 of data storage unit 20.

[0067]

(Color assignment)

The color assignment processor 13 (Fig. 1) next assigns a printable color to the resulting low resolution luminance data. Fig. 5 is a function block diagram of a preferred embodiment of the color assignment processor 13. As shown in Fig. 5, the color assignment processor 13 has an expressible color memory 41, color

assignment input controller 42, printable color count controller 43, color assignment threshold value calculator 44, and color assignment controller 45.

[0068]

The expressible color memory 41 stores the colors that can be printed with a color-limited printer. The color assignment input controller 42 determines the colors used to print an image based on the printable colors stored by the expressible color memory 41 or the colors input from the parameter input controller 12. Once the printable colors usable for printing are determined, the printable color count controller 43 determines the number of printable colors N (including the non-printing color of the paper). Once the printable color count (N) is determined, the color assignment threshold value calculator 44 determines the threshold values for converting the luminance data stored in the luminance data memory 22 to N levels.

[0069]

In general, a color-limited printer is a two color printer, that is, a printer capable of printing two colors, N is therefore 3 and two threshold values are determined for 3-value conversion. Various techniques and methods for downsampling to three levels will be readily apparent to one with ordinary skill in the art. One method, for example, is to calculate a base threshold value for converting the data to two levels, and then based on this base threshold value calculating two threshold values (first and second threshold values) for conversion to three levels. Methods for calculating threshold values for conversion to two and three levels are further described below. The threshold values can also be externally input from the parameter input controller 12 instead of thus obtaining the threshold values from two- or three-value conversion. In this case the input threshold values are used.

[0070]

Once the threshold values are determined, the color assignment controller 45 assigns a printable color to each pixel based on the threshold values.

The print data after assigning printable colors could be stored as the CMYK color data actually used for printing rather than as RGB color data. In this case, however, the print data must be converted to RGB color data by the display controller 14 in order to display the color data on the display unit.

[0071]

Various algorithms can also be used to determine how colors are assigned according to the luminance level. One method, for example, is to assign the N luminance levels according to the luminance level of the color used for printing. Which of the N luminance levels is assigned to what color can also be controlled by input from the parameter input controller 12. This color assignment process is the final step for determining the printed colors, and it is therefore preferable to provide selectable means for manually specifying the threshold values for color assignment and for assigning colors automatically.

[0072]

It is also possible to simply evenly divide 256 level data into two or three parts for conversion to two or three levels as shown in Fig. 7 (a) and (b) rather than using a process such as described above for detecting valleys and determining the threshold values from a luminance distribution curve. As will also be understood from Fig. 7, however, simply dividing the high resolution data into equal parts may not reflect the specific luminance distribution of the image, and it is therefore difficult to predict what the final printed image will actually be like. As an intermediate process it is also possible to, for example, convert to 8 levels first and then evenly divide these eight levels into three parts for color assignment. This method considers the luminance distribution in the low resolution conversion step, and therefore obtains a print image that better reflects the image in the source data.

[0073]

(Preferred embodiment of a print image processing method)

A print image processing method according to the present invention for printing color image data with a limited number of colors is described next with reference to Fig. 8 to Fig. 13.

[0074]

Fig. 8 is a flow chart showing the process for generating a print image using a print image processing method according to a preferred embodiment of the present invention. First, the source data capturing control means 11 (Fig. 1), for example, captures a full-color image from which the print image will be generated, and converts the full-color image to luminance data (S100). The resulting luminance data is then downsampled to low resolution luminance data to facilitate the color assignment process (S200). The low resolution luminance data is then converted to N level data according to the printable color count (N), and the luminance data is then assigned to the N printable colors (S300).

[0075]

(Conversion to luminance data)

The process for converting the color data to luminance data (S100) is described in further detail below with reference to Fig. 9. Fig. 9 is a flow chart of the process for converting full-color data or multicolor data to luminance data in a preferred embodiment of the print image processing method of the invention.

[0076]

Once the source data is captured, the RGB color data for the first pixel is read from the source data (S101). This RGB color data is converted to luminance data by applying the operation shown in equation (2). The process shown in Fig. 9 does this by first weighting the RGB color data for each pixel as shown in equation (1) above (S102), dividing by three to obtain the average (S103), and then storing the resulting average as the luminance data (S104). If RGB color data in the source data has a color depth of 256 levels, this process converts the color data to 256 levels of luminance data. When the process is completed for the first pixel, the same process is applied to the second pixel (S105; no). When steps S101 to S104 have been applied to every pixel in the image

(S105; yes), conversion to luminance data (S100) is completed and step S200 is run.

[0077]

(Downsampling luminance data to fewer luminance levels)

The process for converting the luminance data to low resolution luminance data is described next with reference to Fig. 10. Fig. 10 is a flow chart of step S200 in Fig. 8 for converting luminance data to fewer luminance levels in a print image processing method according to the present invention using below by way of example a process for converting to eight luminance levels.

[0078]

The first step is to determine whether setting the threshold values automatically has been selected (S201). If automatic threshold value setting is not selected (S201; no), operation waits until the threshold values are externally input (S209; no). When the threshold values are externally input (S209; yes), the conversion process for converting the luminance data of each pixel to eight gray levels based on the specified threshold values is run (S210).

[0079]

If automatically setting the threshold values has been selected (S201; yes), it is determined whether to search for the threshold values (S202). If searching for the threshold values is not selected (S202; no), the luminance values at points dividing the 256 luminance levels into substantially eight equal parts are defined as the threshold values (S207), and the luminance data for each pixel is then converted to eight gray levels using these threshold values (S208).

[0080]

If searching for the threshold values is selected (S202; yes), the number of pixels of each luminance level in the image is counted to determine the distribution of the number of pixels of each luminance level in the image (S203). The pixel count distribution curve can also be smoothed at this time. Minimums meeting specific conditions are then detected from the pixel count distribution curve (S204). It should be noted that these minimums can be detected by finding the points where the pixel count stops decreasing and begins increasing such as described above, or using other methods that will be apparent to one with ordinary skill in the art. Note that valleys without a specific size and depth, and valleys having more than a specified number of pixels, can be omitted from use a minimum. This minimum detection step (S204) is described in further detail below.

[0081]

After the minimums of the distribution curve have been detected, the threshold values are defined based on the luminance values of the detected minimums (S205). The luminance values of the minimums can be used directly as the threshold values, or the luminance values can be processed in some way to determine the threshold values. Once the threshold values are determined, the luminance data is converted to fewer gray levels (8 in this example) based on the threshold values (S206).

[0082]

(Minimum detection process)

The step (S204) for detecting the minimums of the distribution curve is described in further detail below with reference to Fig. 11. Fig. 11 is a flow chart showing the minimum detection routine (S204) in a preferred embodiment of the print image processing method according to the present invention.

[0083]

Once the pixel count for each luminance level and the pixel count distribution curve are obtained, a distribution curve smoothing process is run (S241). The pixel count distribution curve does not necessarily need to be stored or processed as an actual curve. It is only necessary to tabulate the luminance data for each pixel in the image as the number of pixels in each luminance level, and store this pixel count for each luminance level. The distribution curve can be smoothed by calculating the average of the pixel count stored for each luminance level with the pixel count of plural adjacent luminance levels, and then using the resulting average as the pixel count for that pixel.

[0084]

The minimums of the smoothed distribution curve are detected after the distribution curve smoothing process (S241) ends. The minimums can be detected by first sequentially comparing the pixel count for each luminance level starting from one end of the distribution curve, and detecting each transition point where after the pixel count decreases continuously the pixel count then starts increasing (S242). Once such a transition point is detected, whether the pixel count increases continuously for some plural number of luminance levels after the transition point (S243) is determined. If the pixel count does not increase for the specified number of consecutive luminance levels (S243; no), the transition point is ignored and the next transition point is detected (S242). If the pixel count increases for the specified number of luminance levels (S243; yes), the transition point is determined to satisfy the detection conditions and the luminance level for that transition point is stored (S244).

It is then determined whether minimum detection has been completed for the entire smoothed distribution curve (S245). If not (S245; no), the next transition point is detected (S242 to S245). If the entire distribution curve has been searched for minimums (S245; yes), the minimum detection process (S204) ends and control returns to the low resolution conversion process (S200). The low resolution conversion process (S200) then steps to the threshold value setting process (S205) and then to the conversion process reducing the luminance data to fewer gray levels (S206) as shown in Fig. 10.

[0085]

(Color assignment process)

The color assignment process is described next with reference to Fig. 12. Fig. 12 is a flow chart of the color assignment process (S300) in the print image processing method of the present invention.

[0086]

When downsampling to, for example, 8 levels is completed, the next task is to assign print colors according to the luminance levels of the resulting low resolution luminance data. The color assignment process (S300) starts by determining whether there has been any external input determining the color assignments (S301). If the color assignment parameters have been externally defined (S301; yes), the specified color is assigned to the specified luminance level (S305). If the color assignment parameters are not specified (S301; no), the printable color count N is determined. The printable color count may be the maximum number of printable or less than this maximum. If the printable color count is less than the maximum number of printable colors, the printable color count is determined by user input. The number of printable colors is previously stored to a specific memory area, or is input during image processing. The number of printable colors is also not determined solely by the number of usable ink colors, and can include halftones that can be printed by dithering the printable ink colors and the non-printing color of the print medium.

[0087]

Once the printable color count N is determined, the luminance data is further converted to N levels based on the printable color count N (S303). To do this, N-1 threshold values are determined, and the luminance data is converted to N levels by applying these threshold values. An example of this N-level conversion process is further described below using a 3-value conversion process. After the luminance data is converted to N levels, colors are assigned according to the luminance levels of the luminance data (S304). Once color assignment is completed, control returns to the main process (Fig. 1 [sic]).

[0088]

The N-level conversion process (S300) is described in further detail below using Fig. 13. Fig. 13 is a flow chart for a 3-value conversion process as a preferred embodiment of the process for converting luminance data to N levels as part of the print image processing method of the invention. Conversion to three levels requires determining two threshold values. To convert the luminance data to three levels, this version of the invention first determines a reference threshold value for converting the luminance data to two levels (S331). Various methods known to one with ordinary skill in the related art can be used for conversion to two values, including, for example, calculating a threshold value for two-value conversion using Ohtsu's method as the reference threshold value (S332). Once this reference threshold value is determined, a first threshold value is calculated based on the reference threshold value. Various known algorithms and methods can be used here, too, and this embodiment uses 2/3 of the reference threshold value as the first threshold value (S332). The second threshold value is also obtained by applying a specific equation based on the reference value (S335 [sic]).

[0089]

This embodiment has been described with reference to a case in which threshold values for converting luminance data to low resolution data are determined by detecting the minimums of a pixel

count distribution curve. The method for determining the threshold values for low resolution conversion shall not be so limited, however, and various other methods could be used. For example, the maximums of the pixel count distribution curve could be detected and the luminance level of the median between adjacent maximums used for the threshold values.

[0090]

(Print image processing: a specific example)

(Gray level conversion using an RGB gradation cube)

Fig. 14 shows various gray level conversion processes referenced to an RGB gradation cube. Fig. 14 (a) shows an RGB gradation cube in which red (R) is on the X axis, green (G) on the Y axis, and blue (B) on the Z axis and color intensity increases gradually along each axis starting from 0 at the origin (0,0,0) to a maximum of 255. In this RGB space black (K) results when each of the colors, red, green, and blue, is at the lowest level and white results when at the highest level. In the cube shown in (a), therefore, the minimum value, that is, black (K), is at coordinates (0,0,0), and the maximum value, white (W), is at the coordinates (255, 255, 255). Figs. 14 (b) to (e) show images of the cube in (a) unfolded to a plan view after applying dithering, error diffusion, simple color reduction, and the image processing method of this invention with the results shown as monochrome figures for use as drawings in a patent application.

[0091]

While the impression is different from an actual color display because only black and white are used in patent drawings, printing with two printable colors is normal when using a color-limited printer, and small spots tend to appear in patterns and the images to be relatively monotone.

[0092]

The unfolded cube shown in Fig. 14 (b) shows the result of color reduction to 8 levels by dithering. As will be known from this figure color reduction by dithering produces fine granular points, which result in image noise when assigned to only a few colors. The image in Fig. 14 (c) likewise shows the result of color reduction by error diffusion. In this case the fine grains create dispersed dots. Fig. 14 (d) likewise shows the result of simple color reduction, which results in a completely different pattern. Fig. 14 (e) results from the image processing method of the present invention, and shows the result of dividing luminance levels to eight levels. Using threshold values to digitally convert the cube to gray levels results in eight patterns, and it will be noted that these patterns vary in stages according to the change in luminance level.

[0093]

(Image processing gradations on a plane)

Fig. 15 (a) shows a gradation image in which black intensity increases gradually from top left down and red intensity increases from top left to right, the result of processing this image by dithering is shown in (b), error diffusion in (c), and the image processing method of this invention in (d), (e), and (f). All of the images were printed in two colors, black and red.

[0094]

While the patterns are slightly different in the dithered and error diffusion images, they both contain a pattern of dispersed dots (b), (c). Image (d) resulting from image processing according to the present invention expresses both the change in luminance and the change in color brightness. While image (d) is also a digital representation, it is a well-defined image free of noise that simply reflects the change in gradation. Image (e) was achieved using the method of the invention to intentionally insert low luminance colors at intermediate luminance levels as a result of color assignment input by the user. Image (f) shows a pattern intentionally created by externally input color assignments using the image processing method of the present invention, and the gradation image is digitally clearly represented.

[0095]

(Exemplary image processing control screen)

Fig. 16 shows an example of an image processing control screen presented by a print image processing apparatus according to a preferred embodiment of the present invention.

[0096]

An image 61 of the source data is presented in the top center of the screen, and the print image 62 resulting from image processing is shown on the right. To get the source data image source data image 61, the user can click on the reference button 63 shown at the top right to select the source file storing the image. The source data capturing control means 11 (Fig. 1) is then activated by this command, the source data captured, and then displayed based by the display controller 14 (Fig. 1).

[0097]

A print parameter input box 64 is provided at the top left of the image processing screen 60. This print parameter input box 64 is used to specify particular parameters, including the model of printer used for printing, paper width, print colors used, and printer resolution.

At the bottom left of the screen is a basic operation control box 65 with various controls for controlling the basic print image creation process and creating and managing the print image data files.

A image processing properties box 70 is located at the bottom center of the screen 60. Basic functions accessible through this properties box 70 include the color reduction function, level correction, and color assignment. The color reduction process is controlled in this properties box 70 using a slider 71 for setting color reduction to one of three levels varying from coarse to fine. In this example setting the slider 71 to the "coarse" position applies color reduction according to the present invention, moving the slider to the middle position selects dithering, and the "fine" position selects error diffusion. The level correction box 72 is used to separately correct each of the RGB luminance levels to one of four settings. The color assignment box 73 enables the user to select either an automatic or manual mode for image processing by the present invention. If the manual mode is selected, the user can then assign each of the eight (1 to 8) luminance levels 74 to one

of three colors (first color, second color, and white (non-printing color)).

[0098]

In the example shown in the image processing screen 60 in Fig. 16, the manual mode is selected, luminance levels 1 and 3 are assigned to the first color, and luminance level is assigned to the second color. This enables the luminance difference of the petals 67 in the cherry blossoms, which are substantially indistinguishable in the source data image 61, to be displayed with different colors so that the petals within the flower petals can be displayed as a clearly distinguishable pattern as indicated by the flower petals 68 in the print image 62.

[0099]

Fig. 17 is used to describe the difference between image processing by the present invention and dithering and error diffusion processes. Fig. 17 (a) shows the numbers assigned to the figures shown in (b), and (b) shows examples of the processed images. The images in (b) were all derived from the same original image, which had a deep, brilliant blue background and cherry blossoms in various light and dark shades of pink. Multiple relatively pale colors were used for the characters.

[0100]

The images shown in (b) are further described below. Images A and A1 in the top row were dithered. Image A was reduced to 8 colors by dithering. Image A1 is the result of printing image A after assigning red, black, and white (non-printing color). A matrix-shaped pattern appears in the background of the print image A1.

Image B is the product of using error diffusion to reduce the original color image to 8 colors, and image B1 is the result of printing image B with red, black and white (non-printing color). A pattern of spots also appears in the background of print image B1.

[0101]

Image C shows the original image with 8 luminance levels, and image C1 shows image C printed with red, black and white (non-printing color). Note that there are no spots in the background, which is printed an even red (which appears as a light black in the figure due to the brightness of the red). Image C2 was also obtained by assigning red, black, and white (non-printing color) to image C, but in this case assigning the luminance level of the cherry blossom petals to red and the luminance level of the blue background to white, manipulating the image for clarity.

[0102]

Using dithering to express colors is described next.

Using two colors of ink (three colors if the non-printing color is white), a 2 x 2 matrix of four dots per pixel and assigning color to each dot, fifteen different colors can be expressed with each pixel. How fifteen printable colors can be expressed, and how an image containing 8 luminance levels is assigned to these fifteen printable colors, are described next with reference to Fig. 18.

Fig. 18 (a) shows the relationship between the 15 colors that can be expressed with four dots per pixel using a printer capable

of printing two colors per dot (three colors including the non-printing color), and the color assignment sliders 81 in the color assignment box 73 shown in Fig. 18 (b). Fig. 18 (b) shows a color assignment box 80 for assigning 8 luminance levels to fifteen colors. In Fig. 18 a black dot (∘) denotes black, a circle (o) denotes red, and a blank denotes a white dot. The values (x,y,z) below each matrix show the number of (white, black, red) dots in the matrix. In other words, the color of each unit pixel is determined by the ratio of color dots in the four dots constituting each pixel.

[0103]

Area a (0 -> 1) in Fig. 13 [sic] shows the matrices containing only white and black dots and shows the range (direction) from a matrix with four white dots (0) to a matrix with four black dots (1). Area b (1 -> 2) shows the matrices containing only black and red dots, and shows the range (direction) from four black dots to four red dots (2). Area c (2 -> 0) shows matrices containing only red and white dots, and shows the range (direction) from four red dots to four white dots. Area d (0 -> 12) shows the matrices variously combining white, red, and black dots, and shows the transition from four white to four black dots.

[0104]

The relationship between the color assignment determined by the position of the color assignment slider 81 in Fig. 18 and areas a, b, and c will be understood from the figures. That is, the pixel changes gradually from white to black as the color assignment slider 81 moves from 0 to 1, from black to red as the slider moves from 1 to 2, from red to white as the slider moves from 2 to 0, and from white to a mixture of white, red, and black as the slider moves from 0 to 12.

The color assignment sliders 81 provided for each luminance level 1 to 8 in the color assignment box 80 in Fig. 18 (b) are used to assign the eight luminance levels to any of the fifteen printable colors. The color assignment box shows a case in which there are two printable colors in Fig. 12 (a) [sic], and in this example the first color is black and the second color is red. In this color assignment box 80 each slider 81 is moved along the scale from 0 -> 1 -> 2 -> 0 -> 12 for each of the eight luminance levels 1 to 8 to assign each luminance level to one of fifteen colors. Fig. 18 (b) shows an example in which special sliders 81 are used, but the printable colors can also be assigned by providing sliders with fifteen stages 0 to 14 according to the brightness of the printed color for each luminance level 1 to 7. Downsampling to an image have the same number of luminance levels as the number N of printable colors is also possible.

[0105]

By thus enabling the user to freely assign the colors that can be printed by the printer, a clear, expressive print image can be created even when the source data image is downsampled to eight levels, even in cases where constant, fixed color assignments can result in important luminance edges being assigned to the same color such that the resulting image is difficult to discern.

[0106]

Furthermore, by increasing the number of assignable colors using dithering or dot gradation and enabling the user to freely assign the printable colors, printer output can be made more expressive even when using a printer, such as a two-color printer, that can only print a limited number of colors.

[0107]

[Effect of the invention]

The present invention can generate a print image based on the luminance levels of the source data image by converting all source data from color data to luminance data by converting the color data of each pixel unit in a source data file containing image data, for example, in multiple colors to luminance data, and then assigning the luminance data of each pixel to a printable color based on the luminance level. This method makes it possible to generate print image data enabling the original image to be printed accurately, clearly and without spots or noise in the print image even when printing with a limited number of colors. In addition to dithering and other color reduction methods, this invention can also assign colors based on the luminance level and apply other image processing operations to print multicolor source images using only a few colors, and thereby provides a print image processing apparatus and method capable of applying numerous image processes.

[Brief Description of the Drawings]

Fig. 1 is a function block diagram of a print image processing apparatus according to a preferred embodiment of the present invention.

Fig. 2 is a table showing the relationship between color depth and luminance for white (W), yellow (Y), cyan (C), green (G), magenta (M), red (R), blue (B), and black (K).

Fig. 3 is a function block diagram of a gradation processing unit according to a preferred embodiment of the present invention.

Fig. 4 is a graph showing as a distribution curve the pixel count distribution stored by the pixel count distribution memory 32.

Fig. 5 is a function block diagram of a color assignment processor according to a preferred embodiment of the present invention.

Fig. 6 is a graph showing luminance data converted to 8 levels based on threshold values 1 to 7 set by the gradation processing unit.

Fig. 7 is a graph showing an example of setting threshold values for two-value or three-value conversion by dividing 256 levels evenly into two parts or three parts.

Fig. 8 is a flow chart of a print image processing method according to a preferred embodiment of the present invention.

Fig. 9 is a flow chart of a process for converting full-color data or multicolored data to luminance data according to a preferred embodiment of a print image processing method according to the invention.

Fig. 10 is a flow chart of low level conversion process according to a preferred embodiment of a print image processing method according to the present invention.

Fig. 11 is a flow chart of a minimum detection process in a preferred embodiment of a print image processing method according to the present invention.

Figure showing a sample display screen for image processing individual objects

Fig. 12 is a flow chart of preferred embodiment of a color assignment process in a print image processing method according to the present invention.

Fig. 13 is a flow chart showing a three-value conversion process as an example of a process for converting luminance data to N-value data as part of a print image processing method according to the present invention.

Fig. 14 shows various level conversion processes using an RGB gradation cube, (a) showing the RGB gradation cube, and (b) to (e) are monochrome representations of the cube shown in (a) converted to a plane figure and then processed by dithering, error diffusion, simple color reduction, and the image processing method of this invention.

Fig. 15 shows the gradation image (a), in which black intensity increases gradually downward from the top left and red intensity increases as a gradient from top left to right, after dithering (b), error diffusion (c), and the method of the present invention (d), (e), and (f), where each of the images was printed using two colors, black and red.

Fig. 16 shows an example of a image processing screen 60 in a print image processing apparatus according to the present invention.

Fig. 17 shows various images illustrating the difference between image processing by means of the present invention, dithering, and error diffusion.

Fig. 18 (a) shows the relationship between the color assignment slider 81 shown in Fig. 12 and fifteen colors that can be expressed by a printer that can printer two colors (three colors including a non-printing color) per dot where each pixel consists of four dots, and (b) shows a sample color assignment dialog box for assigning eight luminance levels to fifteen printable colors.

[KEY TO THE FIGURES]

10 print image processing apparatus
11 source data capturing control means
13 color assignment processor
15 data conversion processor
18 gradation processing unit
20 data storage unit
37 luminance distribution curve
38 smoothing distribution curve
51 low minimum
52 low minimum of smoothing distribution curve
60 image processing screen
61 source data image
62 print image
63 reference button
64 print parameter input box
65 basic operation control box

70 image processing properties dialog box
72 level correction box
73 color assignment dialog box
74 luminance level
80 15-color color assignment dialog box

[Document title] Abstract

[Abstract]

[Problem] To enable color reduction and color assignment processing capable of removing color reduction noise and showing clear contours when producing print image data by assigning print colors after color reduction.

[Means for solving the problem]

Source data is converted to luminance data and usable colors are assigned according to the luminance values of the image represented by the converted luminance levels by means of a source data capturing control unit for obtaining source data containing image data and/or text data containing plural colors; a data conversion processing unit for converting all source data from color data to luminance data by converting color data for each pixel unit in the captured source data to luminance data; and a color assignment processing unit for assigning luminance data for each pixel to a color printable by the printer according to the luminance level.

[Selected figure] Fig. 1

[TEXT IN THE FIGURES]

FIG. 1
IMAGE READER <--> SOURCE DATA CAPTURING CONTROL MEANS 11
INPUT DEVICE <--> PARAMETER INPUT CONTROLLER 12
COLOR ASSIGNMENT PROCESSOR 13
DISPLAY DEVICE <--> DISPLAY CONTROLLER 14
SOURCE DATA READING UNIT 16
SOURCE DATA MEMORY 21
LUMINANCE CALCULATOR AND STORAGE UNIT 17
GRADATION PROCESSING UNIT 18
LUMINANCE DATA MEMORY 22
PRINT DATA MEMORY 23
PRINT DATA OUTPUT CONTROLLER 24

FIG. 2
WHITE
YELLOW
CYAN
GREEN
MAGENTA
RED
BLUE
BLACK

FIG. 3
FROM LUMINANCE CALCULATOR AND STORAGE UNIT 17 -->
PIXEL COUNTER 31
PIXEL COUNT DISTRIBUTION MEMORY 32
DISTRIBUTION CURVE SMOOTHING PROCESSOR 33
MINIMUM DETECTION CONTROLLER 34
FROM PARAMETER INPUT CONTROLLER 12 --> THRESHOLD VALUE SELECTOR 35
LUMINANCE DATA CONVERSION PROCESSOR 36
TO LUMINANCE DATA MEMORY 22

FIG. 4
PIXEL COUNT
LUMINANCE DISTRIBUTION
AFTER SMOOTHING

FIG. 5
FROM PARAMETER INPUT CONTROLLER 12
EXPRESSIBLE COLOR MEMORY 41
COLOR ASSIGNMENT INPUT CONTROLLER 42
PRINTABLE COLOR COUNT (N) CONTROLLER 43
COLOR ASSIGNMENT THRESHOLD VALUE CALCULATOR (N-LEVEL PROCESSING UNIT) 44
FROM LUMINANCE DATA MEMORY 22 --> COLOR ASSIGNMENT CONTROLLER 45
TO PRINT DATA MEMORY 23

FIG. 6
LUMINANCE LEVEL ADJUSTMENT
NUMBER OF LEVELS [8]
OK DEFAULTS CANCEL

FIG. 7
2-LEVEL CONVERSION
THRESHOLD VALUES FOR 2-LEVEL CONVERSION
OK DEFAULTS PREVIEW (P)

3-LEVEL CONVERSION
THRESHOLD VALUES FOR 3-LEVEL CONVERSION
OK DEFAULTS PREVIEW (P)

FIG. 8
CREATE PRINT IMAGE
S100 CONVERT FULL-COLOR IMAGE TO GRAY SCALE IMAGE
S200 DOWNSAMPLE LUMINANCE DATA TO FEWER LUMINANCE LEVELS (8 LEVELS)
S300 COLOR ASSIGNMENT PROCESS
END

FIG. 9
CONVERSION TO LUMINANCE DATA
S101 READ RGB DATA FOR FIRST PIXEL IN SOURCE IMAGE
S102 WEIGHT READ RGB DATA 3:1:6
S103 DIVIDE WEIGHTED DATA BY 3 (AVERAGING)
S104 STORE DIVIDED DATA AS LUMINANCE DATA FOR CORRESPONDING PIXELS
S105 ALL PIXELS CONVERTED?
RETURN

FIG. 10
CONVERSION TO 8 GRAY LEVELS
S201 SET THRESHOLD VALUES AUTOMATICALLY?
S202 SEARCH FOR THRESHOLD VALUES?
S203 CALCULATE PIXEL COUNT DISTRIBUTION FOR EACH LUMINANCE LEVEL
S204 DETECT DISTRIBUTION CURVE MINIMUMS
S205 SET THRESHOLD VALUES BASED ON DETECTED MINIMUMS
S206 CONVERT PIXEL LUMINANCE DATA USING THRESHOLD VALUES
S207 SET THRESHOLD VALUES AT POINTS DIVIDING LUMINANCE RANGE INTO 8 EQUAL PARTS
S208 CONVERT PIXEL LUMINANCE DATA USING THRESHOLD VALUES
S209 THRESHOLD VALUES INPUT?
S210 CONVERT PIXEL LUMINANCE DATA USING SPECIFIED THRESHOLD VALUES
RETURN

FIG. 11
MINIMUM DETECTION
S241 SMOOTH DISTRIBUTION CURVE
S242 DETECT POINT WHERE PIXEL COUNT STARTS INCREASING AFTER DECREASING CONTINUOUSLY FOR A SPECIFIED NUMBER OF POINTS
S243 PIXEL COUNT INCREASES A SPECIFIED NUMBER OF TIMES?
S244 STORE LUMINANCE LEVEL OF DETECTED TRANSITION POINT
S245 DETECTION COMPLETED FOR ENTIRE CURVE?
RETURN

FIG. 12
S300 COLOR ASSIGNMENT PROCESS

S301 COLOR ASSIGNMENTS INPUT?
S302 DETERMINE NUMBER (N) OF PRINT COLORS
S303 CONVERT LUMINANCE DATA TO N LEVELS (CALCULATE THRESHOLD VALUES FOR N LEVEL CONVERSION)
S304 ASSIGN PIXEL UNIT LUMINANCE DATA TO PRINTABLE COLORS
S305 ASSIGN PIXEL UNIT LUMINANCE DATA TO SPECIFIED COLORS
RETURN

FIG. 13
S303 3-VALUE CONVERSION
S331 CALCULATE REFERENCE THRESHOLD VALUE
S332 CALCULATE TV1 = REFERENCE VALUE * 2/3
S333
S334 CALCULATE TV2 = REFERENCE VALUE + (7-REFERENCE VALUE) * 1/3
S335 CONVERT LUMINANCE DATA TO 3 LEVELS BASED ON TV1, TV2
RETURN

FIG. 16
SOURCE FILE D¥temp¥PATENTIMAGE¥image5ipg
REFERENCE BUTTON 63
PRINTER INFORMATION 64
NAME
PAPER WIDTH
COLOR 1
COLOR 2
RESOLUTION
COMMUNICATION PARAMETERS
PORT
ADJUST LUMINANCE LEVEL
NEW OUTPUT TO FILE
EDIT SAVE TO PRINTER
PREVIEW MANAGE PRINTER FILES
TEST PRINT QUIT

FIT TO PAPER WIDTH

PROPERTIES
SINGLE COLOR
COLOR REDUCTION
coarse fine
LEVEL CORRECTION
COLOR ASSIGNMENT (BY LUMINANCE LEVEL)
AUTOMATIC MANUAL
COLOR 1 COLOR 2 WHITE
LOW (1) HIGH (8)

FIG. 17
DITHERED
ERROR DIFFUSION
METHOD OF THE INVENTION

FIG. 18
SLIDER 81

AUTOMATIC MANUAL
COLOR 1 COLOR 2
black red
LOW (1) HIGH (8)
COLOR ASSIGNMENT SLIDER 81